International Journal of Mechanical and Production Engineering Research and Development (IJMPERD)
ISSN (P): 2249-6890; ISSN (E): 2249-8001
Vol. 9, Issue 4, Aug 2019, 177-182

THE MICROSTRUCTURE, HARDNESS AND XRD ANALYSIS OF IN-SITU Al 6061-TiB_2 METAL MATRIX COMPOSITES WITH DIFFERENT REACTION HOLDING TIMES

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ABSTRACT

Aluminum Metal Matrix Composite (AMMC) is studied and extensively established for various commercial and industrial applications due to mechanical properties, low thermal expansion coefficient and low density, higher thermal and electrical behavior and better corrosion resistance. In this experimental study, Al6061-TiB_2 Metal Matrix Composites prepared by stir casting and in-situ techniques by the introduction of halide saltsKBF$_4$and K_2TiF_6in the Al 6061 molten matrix at 850 °C. The reinforcement phase, TiB_2 formed due to the exothermic reaction between the molten Al 6061 alloy and halide salt that is equally distributed throughout the matrix due to the combined effect of stir casting and in-situ techniques. We study the hardness, XRD analysis and microstructure of the composites with diverse reaction holding times from a minimum of 15 minutes to a maximum of 60 minutes. The XRD analysis and microstructure show the distribution of adequate TiB_2 particles in the production of Al 6061-TiB_2Metal Matrix composite comparable to other AMMC candidates. In the current study, it was found that 30minute's reaction holding time ensures uniform distribution and maximum hardness of the reinforcement phase, TiB_2 at the matrix phase, Al 6061 alloy.

KEYWORDS: AMMC, Stir Casting, in-situ, K_2TiF_6 and KBF_4 & Reaction Holding Time

Received: Apr 24, 2019; **Accepted**: May 14, 2019; **Published**: Jun 19, 2019; **Paper Id**.: IJMPERDAUG201919

Original Article

INTRODUCTION

Metal Matrix Composites (MMCs) have emerged as a major class of structural materials, transportation, thermal wear and electrical applicationschiefly as a result of their ability to reveal higher strength-to-cost and strength-to-weight ratio when related to equivalent monolithic commercial alloys. Aluminum based particulate reinforced metal matrix composites have ascended as a major class of high performance materials for use in the automobile, aerospace industry, transportation and chemicals industries due to their improved strength, increased wear resistance and high elastic modulus over conservative base connections. Recently, in-situ techniques have been industrialized in the country to produce aluminum-based metal matrix composites [1-12], which can lead to well adhesion to the interface and hence have better mechanical properties. In-situ compounds are multiphase constituents where the reinforcement phase is complete within the matrix during the composite manufacturing. There are several ways to manufacture Al-TiB_2elements, but in-situ access becomes more important due to the simplicity of its production. The strong bonding of TiB_2 with the Al alloy matrix has been proved as a control factor contributing to upgraded wear resistance of the components; results on in-situ processing of these composites are slight [7-12]. Greater attention is focused on the reinforced metal matrix components for tribological applications

due to MMC's benefits such as high load capacity, excellent sliding resistance and low density. MMCs containing a fraction of the high-volume carbide, nitrite or oxide particles are often the material which requires better resistance to wear.

TiB_2 emerged as an extraordinary reinforcement because TiB_2 exhibits excellent properties such as high hardness (86 HRA or 960 HV), high elastic modulus (530 x 10^3GPa), high melting point (2790°C) and better thermal stability. Besides, it has plastic deformation temperature resistance. TiB_2 particles do not react with molten aluminum, thereby preventing the formation of flimsy reaction products in the matrix improvement levels. The Al-TiB_2 compounds thus exhibit some beneficial and exclusive properties [5, 14].

The processing of in-situ composites in the country involves the synthesis of the amplification phases directly within the matrix. This approach is in contrast to the ex-situ components where reinforcements are synthesized separately and then placed in the matrix during a secondary process such as melting, infiltration or powder processing [2].

The current work is largely limited to the synthesis and microstructural characterization of in-situ Al 6061-TiB_2 MMCs instead of the molten Al 6061 alloy reaction with $KBF_4$and K_2TiF_6salts. The main purpose of this work is the develop an Al 6061-TiB_2 in-situ MMCs with different reaction holding times ranging from a minimum of 15 minutes to a maximum of 60 minutes and to find the optimal reaction holding time which gives the best composition of studies microstructure, hardness and XRD analysis.

EXPERIMENTAL PROCEDURE

Aluminium alloy 6061 was used as the base metal. Table -1 gives the chemical composition of Al 6061.

Table 1: Chemical Composition of Al 6061

Element	Mg	Si	Mn	Cu	Fe	Ti	V	Al
Mass %	1.04	0.62	0.53	0.31	0.19	0.04	0.02	Bal

Two types of halide salts namely KBF_4 and K_2TiF_6 were used to synthesize the TiB_2 reinforcement.

Processing: Aluminum alloy was heated at 850 °C to get the molten state, after which the two types of salts were added to the molten alloy in the atomic ratio in accordance with Ti/2B using a mild steel stirrer coated with zirconia in order to avoid contamination of the molten metal. The chemical reaction between the two salts and the molten aluminum alloy was developed to form the TiB_2particles in aluminum alloy based on the following reactions:

$$3K_2\,TiF_6 + 22Al + 6KBF_4 \rightarrow 3Al_3\,Ti + 3AlB_2 + 9kAlF_4 + K_3\,AlF_6 + \text{Heat} \tag{1}$$

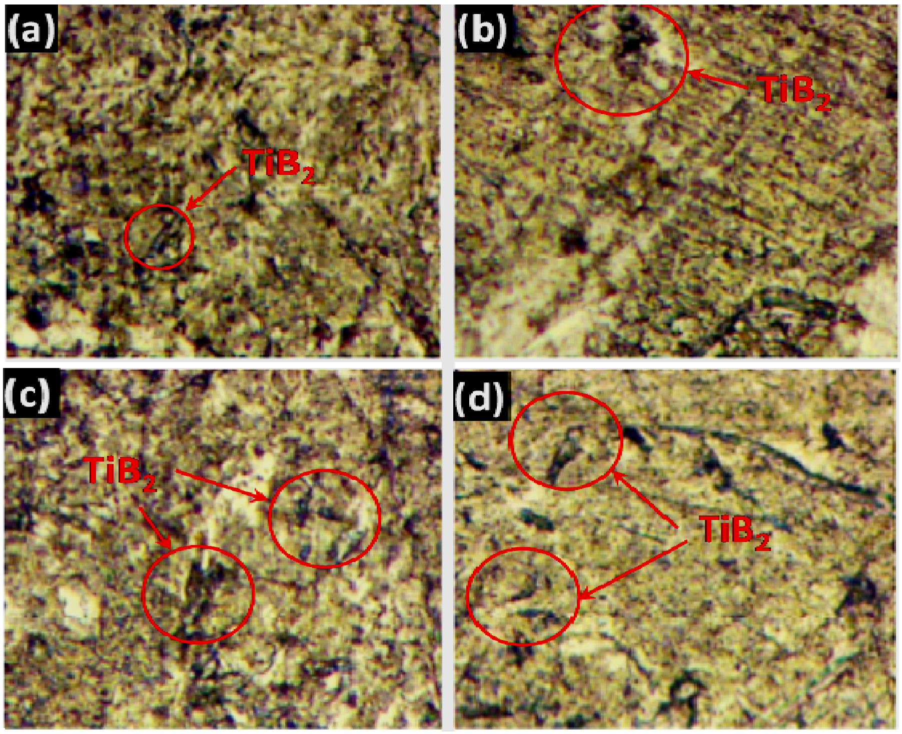
$$3Al_3\,Ti + 3AlB_2 \rightarrow 12Al + 3TiB_2 \tag{2}$$

The chemical reaction period was changed in steps from 15 minutes to 60 minutes at 850 °C to study the TiB_2 growth rate. Composites with different reaction holding times were thrown into bars of 16 mm diameter after skimming off the cryolite slag. Specimens have been prepared for the study of microstructure, XRD analysis and hardness of various components with different reaction holding times.

RESULTS AND DISCUSSIONS

Microstructure

Figures 1 (a) to (d) show the optical microspheres of Al 6061-TiB_2 composites with different reaction holding times of 15 minutes, 30 minutes, 45 minutes and 60 minutes respectively.



Figures 1 (a) to (d): Microstructures of Al 6061-TiB_2 Metal Matrix Composites with Reaction Holding Times (RHTs) of 15 Minutes, 30 Minutes, 45 Minutes and 60 Minutes Respectively

TiB_2 precipitation can be observed in all the microscopic images acquired at different holding times. When the holding time is 15 minutes, TiB_2 deposits are very small and therefore TiB_2 grain formation is likely to begin during this time. By comparing the microscopic images obtained at each holding, we can clearly distinguish the precipitated TiB_2 nature. In general, as the holding time is increased the grain size also growing even through the Ostwald ripening process, where larger grains are further grown at the expense of smaller grains. The grain growth observed here can be a thermally activated process and the Al 6061 Aluminum matrix serves as a medium for transporting ions. It is important to note that, as the holding time increases the distribution of grains are also changed. The best distribution was observed in the microscopic image corresponding to a holding time of 30 minutes (Figure-1b). In sample images taken after 45 minutes and 60 minutes (Figures-1c and 1d), the large TiB_2precipitates and their clusters are visible. The presence of such aggregates and large grains may affect the mechanical properties of the constituents.

Hardness

Brinell Hardness Tests were performed for both basic alloy and composites with varying reaction holding times. The test results are tabulated as shown in TABLE-2

Table 2: Hardness of Alloy and Composites with different Reaction Holding Times (RHTs)

Material	Al 6061 (as cast)	Al 6061-TiB_2	Al 6061-TiB_2	Al 6061-TiB_2	Al 6061-TiB_2
RHT (min)	0	15	30	45	60
Hardness (BHN)	89	110	118	114	112

Figure 2 shows the graph of hardness Vs reaction holding time for the base alloy and the composites with different reaction holding times.

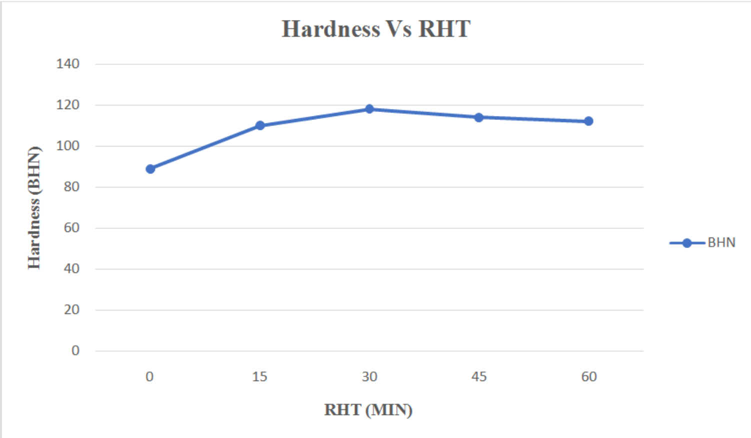


Figure 2: Graph of Hardness (BHN) Vs RHT (min)

XRD Analysis

The XRD models of Al alloy compositions obtained at different holding times are shown in Figure 2a and the corresponding reference models JCPDS (TiB_2 - JCPDS 75-0967 and Al-JCPDS 89-2837) are shown in Figure 2b. As described in the microstructure images, the gradual increase in the TiB_2 phase with the holding time can be observed here. The TiB_2 level intensity increase in the XRD model with time holding can be attributed to percentage growth in the TiB_2 phase in the composite matrix of the holding time and the corresponding increase in grain.

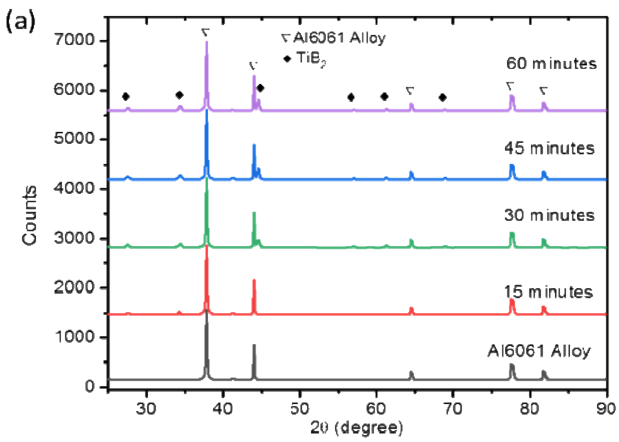


Figure 2a: XRD patterns of the Al6061 alloy Composites Prepared at different Reaction Holding Time

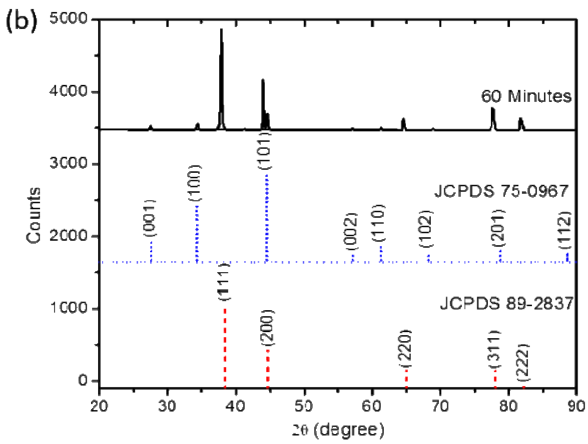


Figure 2b: Standard Reference Patterns of Al and TiB_2 Compared with the Composite

CONCLUSIONS

All Al 6061-TiB_2 composites were successfully synthesized by introducing halide salts KBF_4 andK_2TiF_6into the Al 6061 alloy melt at 850 ^{0}C. XRD studies conform the TiB_2 formation. TiB2, which is the reinforcement phase, is equally distributed uniformly by the stir casting method. TiB_2 is a pure interface made with Al 6061 alloy because of in-situ synthesis method. Microstructure, hardness and XRD analysis showed that Al 6061-TiB_2 composite synthesized with 30 minutes of reaction holding time gave the best results compared to other good candidates of the aluminum alloy matrix composites.

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